

OBLIQUE IMPACT: PROJECTILE RICHOCHET, CONCOMITANT EJECTA, AND MOMENTUM TRANSFER: Donald E. Gault, Murphys Center of Planetology, Box 833, Murphys, CA 95247 and Peter H. Schultz, Dept. Geolog. Sciences, Brown University, Providence, R.I. 02912

Experimental studies of oblique impact (1) indicate that projectile ricochet occurs for trajectory angles less than 30° and that the ricocheted projectile (fragments), accompanied by some target material, are ejected at velocities that are a large fraction of the impact velocity. Because the probability of occurrence of oblique impacts less than 30° on a planetary body is about one out of every four impact events, oblique impacts would seem to be a potential mechanism to provide a source of meteorites from even the largest atmosphere-free planetary bodies (Ceres, Moon, Mars?).

Because the amount of "richocheted" target material cannot be determined from results in (1), additional experiments in the Ames Vertical Gun have been undertaken toward that purpose using pendulums, one to measure momentum of the richocheted projectile and concomitant target ejecta, and a second to measure the momentum transferred from projectile to target. Witness plates downrange from the point of impact provide a basin for estimating the velocities of the projectile fragment(s). The current results are limited to targets of #24 sand, aluminum and pyrex spheres, with velocities ranging from $V_i = 1 - 8$ km/s and impact angles from 7.5° to 45° . Pendulum motions are recorded on high frame-rate video (200 fps) and movie (400 fps) cameras.

The current results indicate that for increasing angle of impact the mass of "richocheted" target material also increases but the ejection velocity decreases. For impact at 7.5° the aluminum projectile fragments richocheted with a mean velocity of $0.82 V_i$ and were accompanied with target material in excess of 0.27 of the projectile mass. At 15° and 30° angles, velocity and target mass fractions are 0.55 and >0.65 , and 0.2 and >2.0 , respectively. Target masses with pyrex projectiles may be even greater. These preliminary results support oblique impacts as a source of meteoritic material, but the physical condition (i.e. shock state) of the ejecta remains an uncertainty that must be addressed before any final conclusions can be reached.

The momentum transfer efficiency, as noted in (2,3) is significantly less than the 50 - 100% commonly believed. For aluminum spheres the efficiency decreases with increasing velocity and increases with increasing impact angle; from 12% at 1 km/s to 8% at 6 km/s for 15° impacts; from 27% at 2.3 km/s to 17% at 5.3 km/s for 30° ; and 34% at 5.5 km/s for 45° . An intriguing observation is that after impact (<10 ms) there is consistently a very small uprange displacement of the target pendulum before the initiation of the large, final downrange movement that occurs during the time for completing crater formation (<100 ms). It is speculated that the uprange motion is triggered by the momentum transferred during the time interval of projectile impact and ricochet which is then cancelled by a much larger down-range momentum component during crater formation and the return of the main mass of ejecta to the target surface. This suggests that for oblique impacts for which most or all ejecta escapes from the planetary body the momentum

transfer is negative (i.e., uprange direction) and would tend to cause the body to rotate "against" the direction of the trajectory of the impacting projectile. Further experiments are required to clarify these results and to examine any effects of curvature of the target surface.

(1) Gault, D.E. and Wedekind, J.A. (1978) Proc. Lunar Planet. Sci. Conf., 9th, p. 3843-3875. (2) Davis, D.R. and Weidenschilling, S.J. (1982) Lunar and Planet. Sci. XIII, p. 740-741. (3) Schultz, P.H. and Gault, D.E. (1986) Lunar and Planet. Sci. XVII, p. 781-782.